Climate Extremes and Variability in Chesapeake Bay

Part I: Past, Present, and Future Extreme Climate Trends

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Prepared for

The Chesapeake Bay National Estuarine Research Reserves

Foreword

Chesapeake Bay is an American treasure with iconic organisms ranging from the delectable blue crab to the majestic great blue heron. Speak to anyone living near its shorelines and you will hear childhood stories of catching rockfish, eating local oysters, and even cheering for the Maryland Terrapins, named after a beloved brackish water turtle.

However, climate change is a pressing issue facing the coastal ecosystems in Chesapeake Bay, affecting not only the organisms who live there, but also the livelihood and identify of its coastal residents. More specifically, changes in extreme climate events, from the intensity of rainfall to the frequency of warmer-than-normal winters, threaten the ecosystem health of Chesapeake's shorelines.

Extreme climate events, or those that measure the intensity, duration, and frequency of temperature and precipitation events, can be the deciding factors in habitat suitability for many organisms. That is, the magnitude of temperature or amount of rainfall affects the physiological thresholds of organisms. For example, one would not expect to see a polar bear living in the tropics just as you would not expect to see a dry-weather cactus living in a rainforest. Thus, changes in extreme climate can affect where organisms can live and dictate how well they can survive.

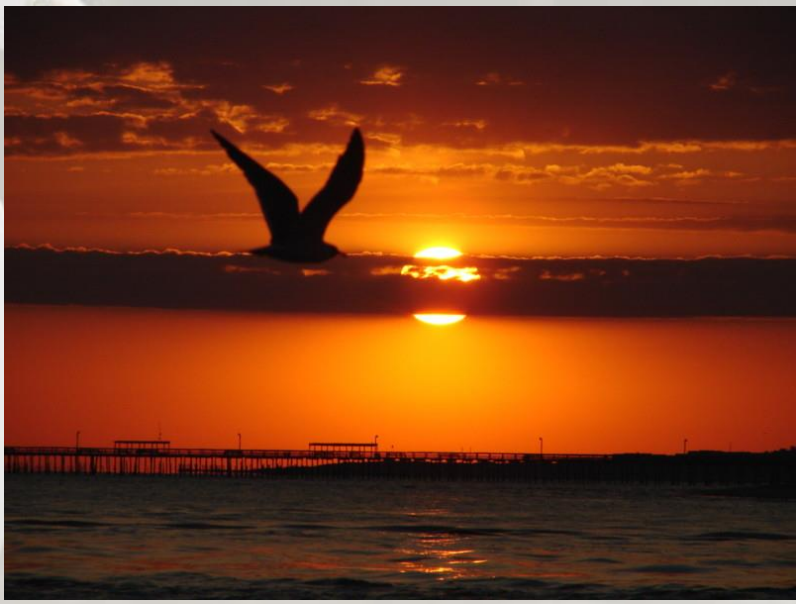
This document summarizes the major trends, and non-trends, of 26 extreme climate indicators in Chesapeake Bay, with a focus on the North and South Chesapeake regions. For that purpose, North Chesapeake is a proxy for the three Chesapeake Bay National Estuarine Research Reserves (CBNERR) in Maryland and South Chesapeake is a proxy for the four CBNERR sites in Virginia.

Executive Summary Bullets

- Fewer cold-based events
- More warm-based events

- Decrease in below average cool days and nights
- Increase in above average warm days and nights
- Lengthening of the growing season

- Increase in total annual precipitation
- Increase in precipitation intensity
- Increase in amount of wet days, primarily observed in north



"There is such a thing as being too late, and when it comes to climate change, that hour is almost upon us." –POTUS at COP21

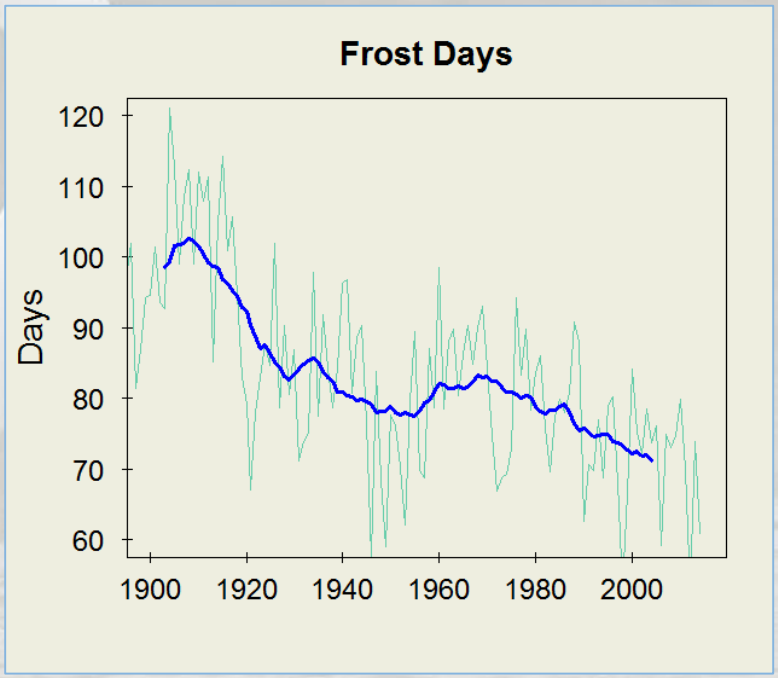
Frost Days

Number of days when the daily Tmin is < 0°C.

CBNERR-MD: -3.3 days/decade (strong confidence)

CBNERR-VA: -2.8 days/decade (strong confidence)

Future: -2.2 to -4.6 days/decade (strong confidence)



Tweetables: Fewer frost days could allow new agricultural pests & disease to move into the Chesapeake region.

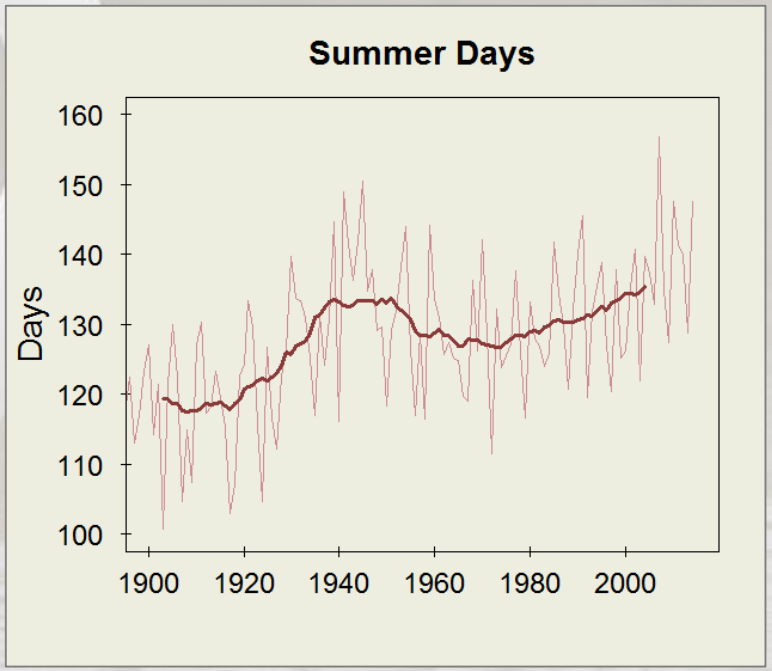
Summer Days

Number of days when the daily Tmax is > 25°C.

CBNERR-MD: -1.9 days/decade (high confidence)

CBNERR-VA: +3.6 days/decade (strong confidence)

Future: +3.0 to +7.0 days/decade (strong confidence)



Tweetables: Summer Days patterns in Chesapeake Bay are highly variable, but the future predicts more are likely.

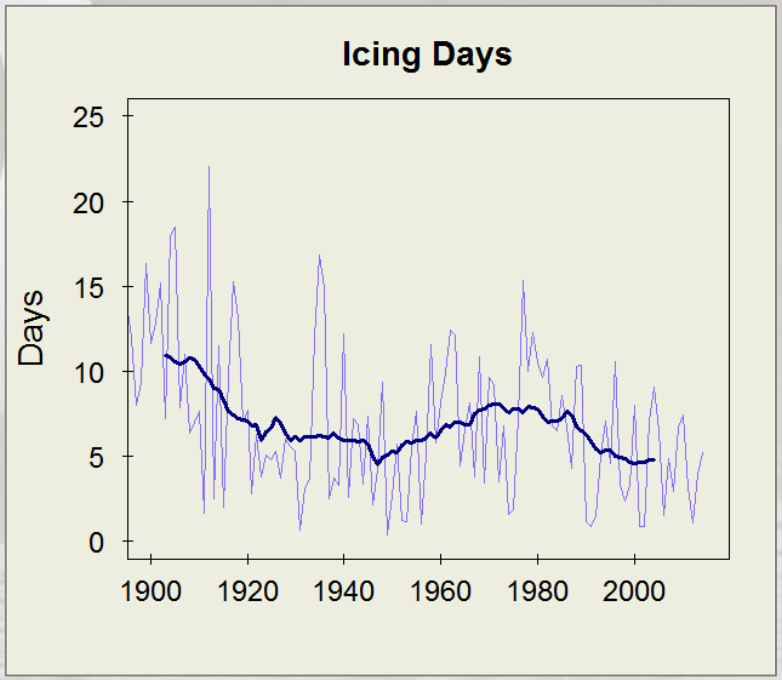
Icing Days

Number of days when the daily Tmax is < 0°C.

CBNERR-MD: -0.3 days/decade (strong confidence)

CBNERR-VA: -0.5 days/decade (strong confidence)

Future: -0.71 to -1.2 days/decade (strong confidence)



Tweetables: Fewer days that never get above freezing could hasten bud burst timing in flowering trees

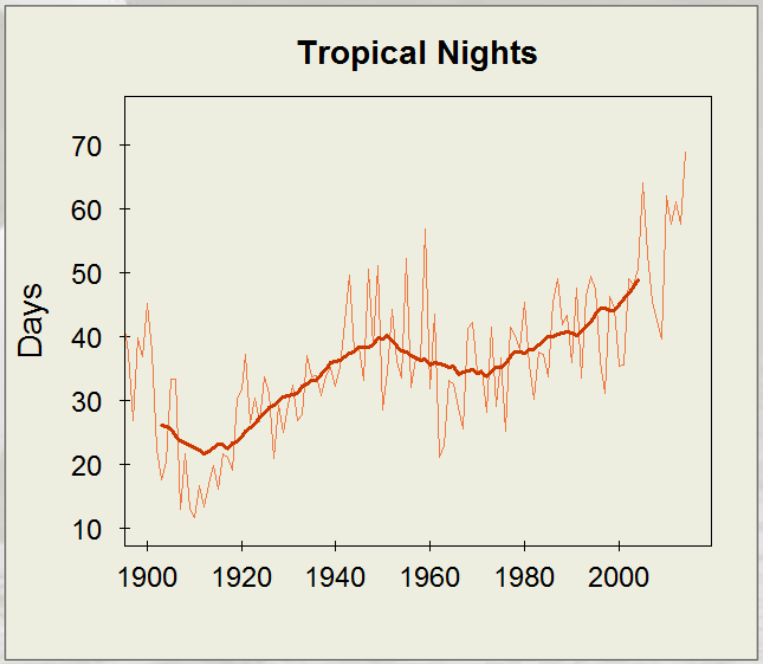
Tropical Nights

Number of days when the daily Tmin is > 20°C.

CBNERR-MD: +4.1 days/decade (strong confidence)

CBNERR-VA: +2.0 days/decade (strong confidence)

Future: -3.6 to +8.0 days/decade (strong confidence)



Tweetables: Declines in crop yields, including rice, corn, and soybeans have been correlated to increased nighttime temperatures

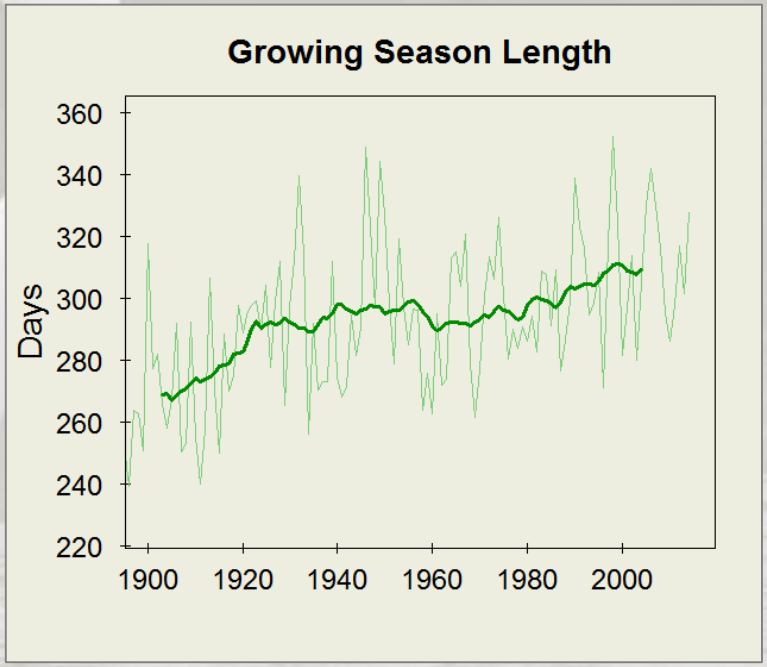
Growing Season Length

#days between the 1st span of 6 days when Tmean is >5°C and the 1st span of 6 days after July 1st when Tmean is <5°C.

CBNERR-MD: +1.7 days/decade (strong confidence)

CBNERR-VA: +4.4 days/decade (strong confidence)

Future: -2.7 to 5.5 days/decade (strong confidence)



Tweetables: A longer growing season may mean a longer allergy season according to the USDA.

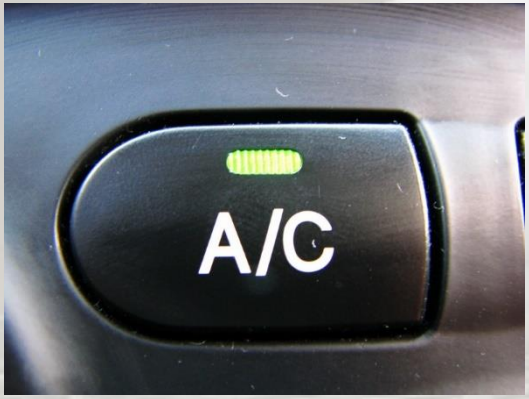
Warm Spell Duration Index

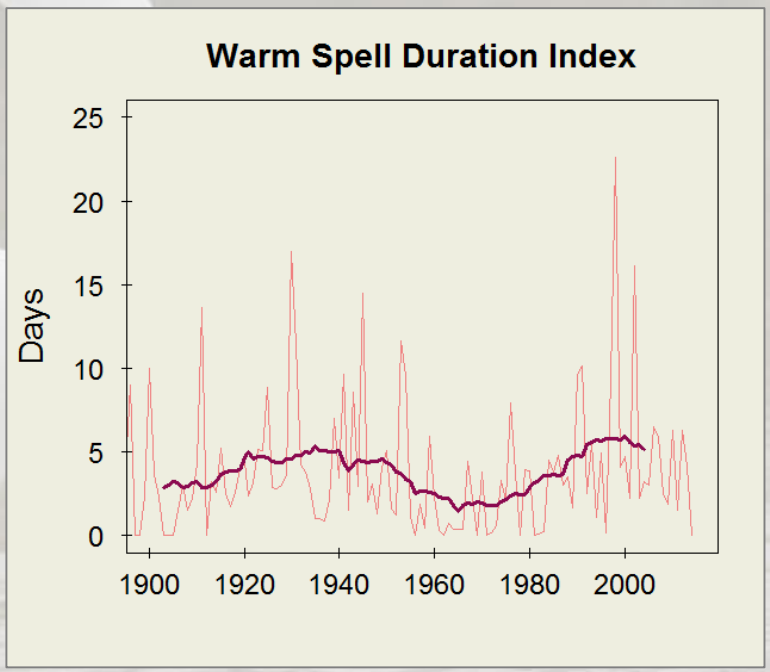
The longest span of at least 6 consecutive days when Tmax is > 90th percentile.

CBNERR-MD: No trend (low confidence)

CBNERR-VA: +0.3 days/decade (strong confidence)

Future: +4.0 to +15.8 days/decade (strong confidence)





Tweetables: Warm spells could get 4 to 16 days longer in the next century! More AC means more emissions!

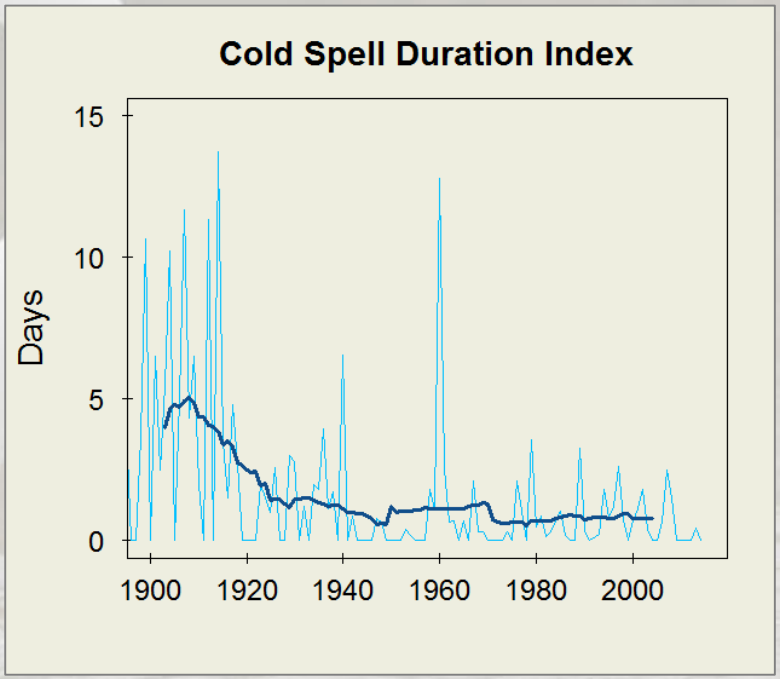
Cold Spell Duration Index

The longest span of at least 6 consecutive days when Tmin is < 10th percentile.

CBNERR-MD: No trend (low confidence)

CBNERR-VA: No Trend (confident in no trend)

Future: -0.12 to -0.07 days/decade (strong confidence)



Tweetables: We have been experiencing more years without a cold spell but variability means cold spells are still possible.

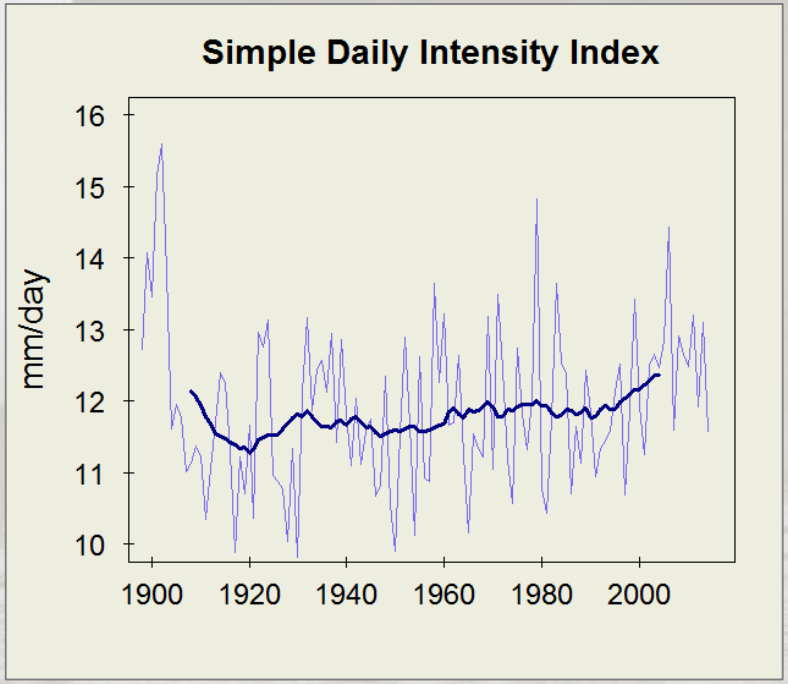
Simple Daily Intensity Index

Ratio of the total annual amount of precipitation by the total number of days with precipitation.

CBNERR-MD: +0.2 mm/day/decade (high confidence)

CBNERR-VA: No Trend (low confidence)

Future: +0.09 to +0.13 mm/day/decade (strong confidence)



Tweetables: In the next century, precipitation is likely to intensify throughout Chesapeake Bay.

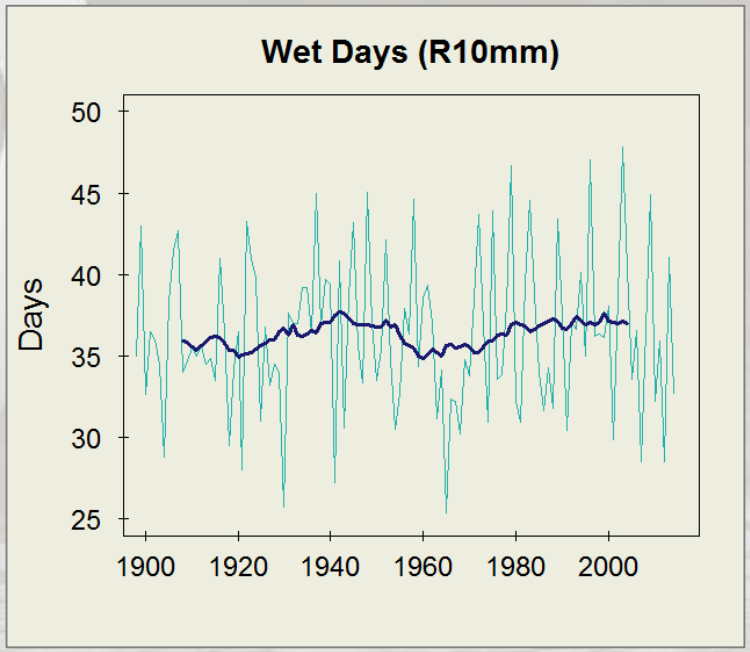
Wet Days (R10mm)

The annual count of days with >10mm of precipitation.

CBNERR-MD: +0.4 days/decade (high confidence)

CBNERR-VA: No Trend (confident in no trend)

Future: +0.19 to +0.08 days/decade (low, high* confidence)



Tweetables: Over the last century, a coastal Maryland resident has experienced 4 more umbrella-required days

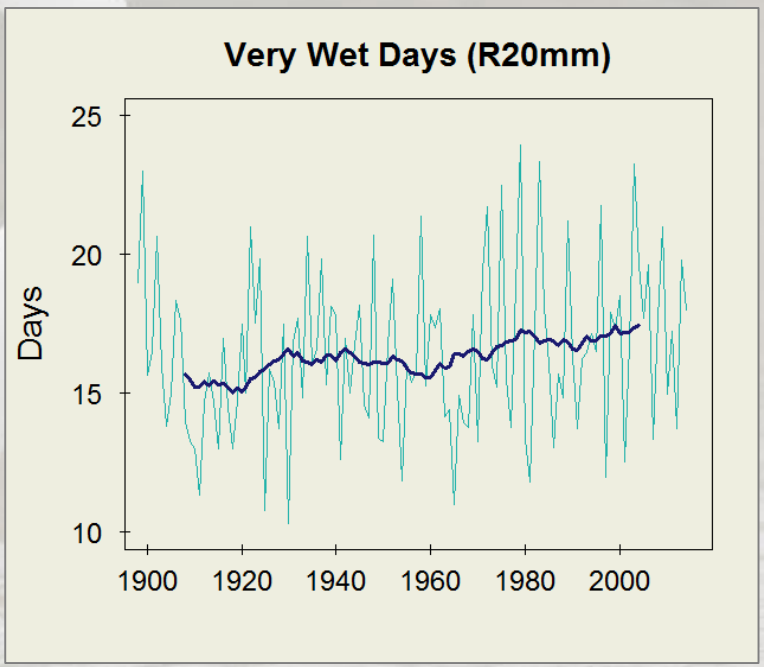
Very Wet Days (R20mm)

The annual count of days with >20mm of precipitation.

CBNERR-MD: +0.5 days/decade (high confidence)

CBNERR-VA: No Trend (confident in no trend)

Future: +0.21 to + 0.27 days/decade (strong confidence)



Tweetables: More very wet days could mean more run-off or road flooding in coastal Maryland.

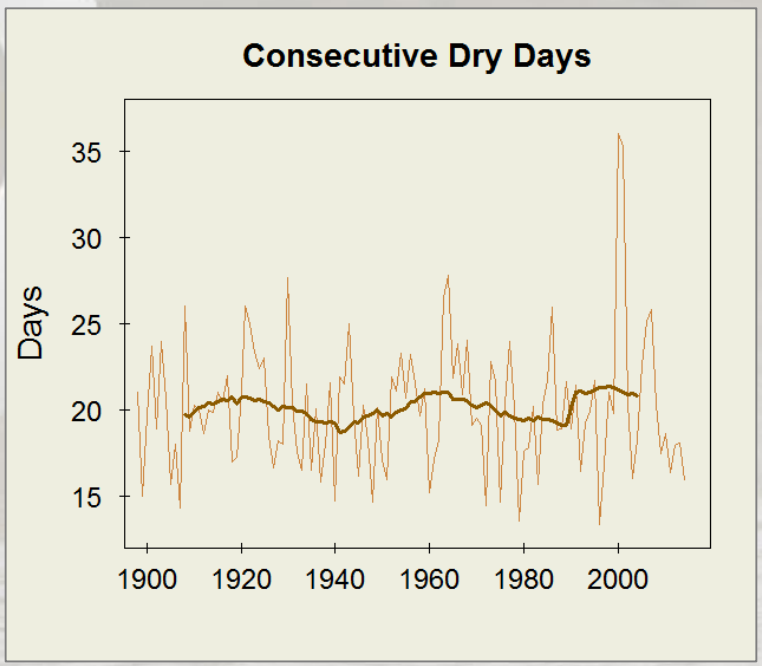
Consecutive Dry Days

The longest span of days with no precipitation.

CBNERR-MD: +0.2 days/decade (high confidence)

CBNERR-VA: No Trend (confident in no trend)

Future: +0.08 to +0.27 days/decade (low*, high confidence)



Tweetables: The longest annual dry spell could get 1 to 3 days longer in the future.

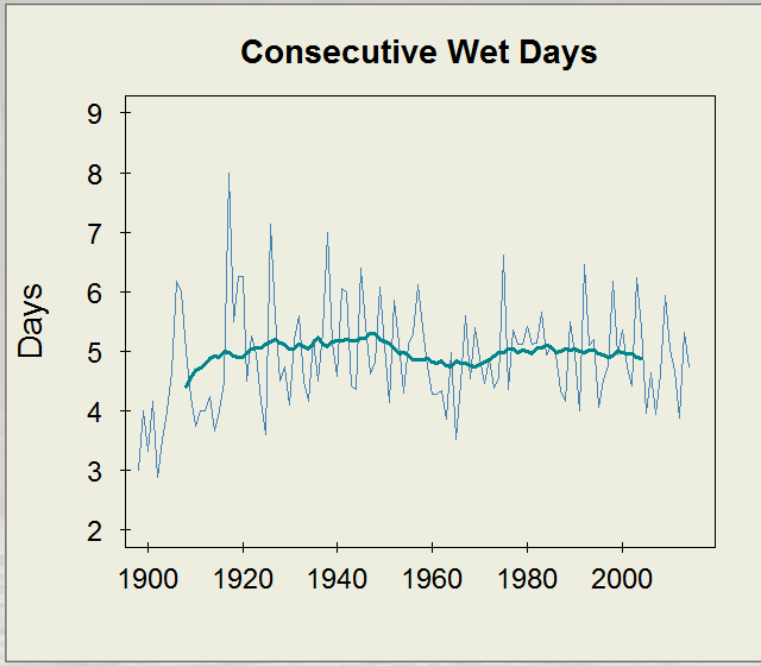
Consecutive Wet Days

The longest span of days with >1mm of precipitation.

CBNERR-MD: -0.1 days/decade (high confidence)

CBNERR-VA: +0.03 days/decade (low confidence)

Future: +0.1 to 0.0 days/decade (low confidence and confident in no trend*



Tweetables: Wet spells do not appear to be changing in the Chesapeake bay region.

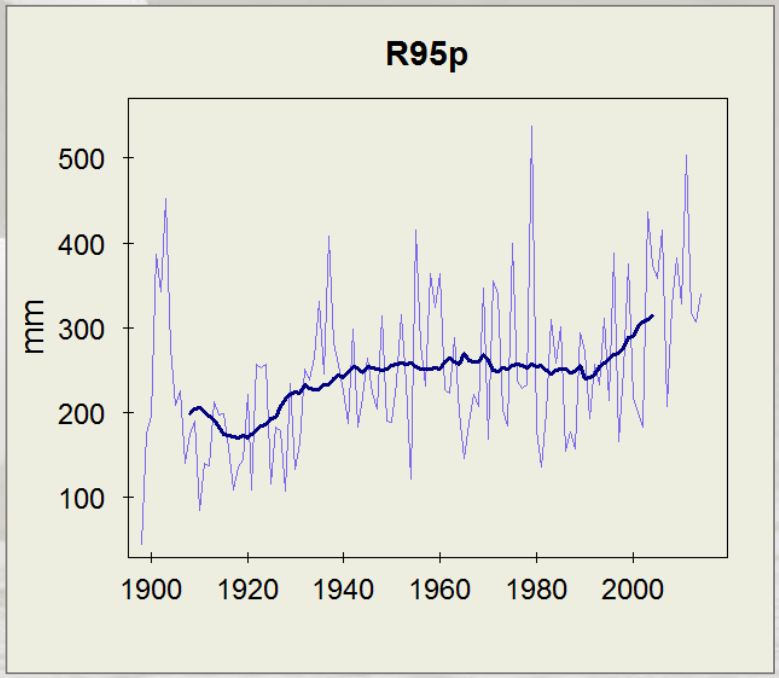
R95p

The amount of precipitation which exceeds the 95th percentile.

CBNERR-MD: +14.8 mm/decade (strong confidence)

CBNERR-VA: +2.8 mm/decade (strong confidence)

Future: +12.6 to +19.7 mm/decade (strong confidence)



Tweetables: More precipitation could increase nuisance algal bloom occurrences due to excess nutrient run-off.

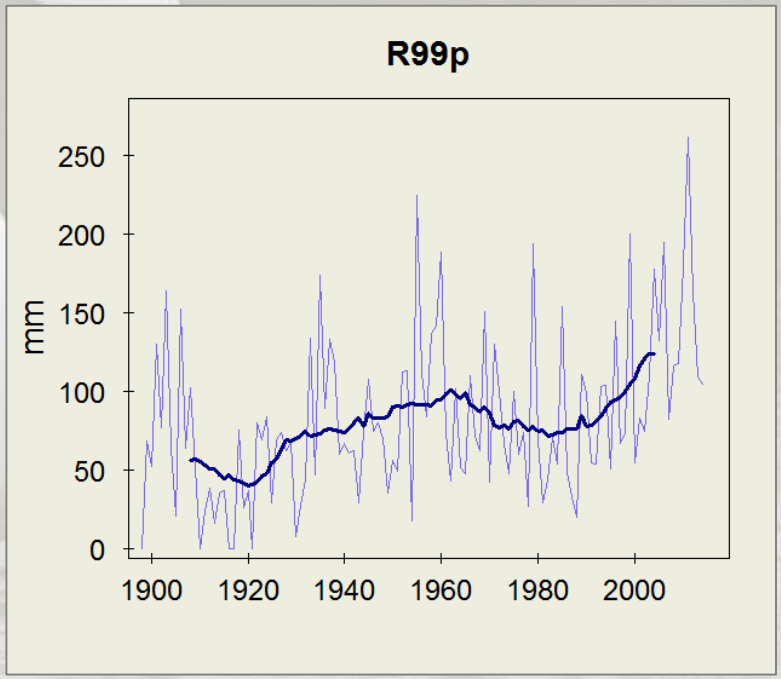
R99p

The amount of precipitation which exceeds the 99th percentile.

CBNERR-MD: +4.8 mm/decade (high confidence)

CBNERR-VA: No Trend (confident in no trend)

Future: +8.2 to +13.6 mm/decade (strong confidence)



Tweetables: More intense precipitation events could change the magnitude of storm water and sewage overflow

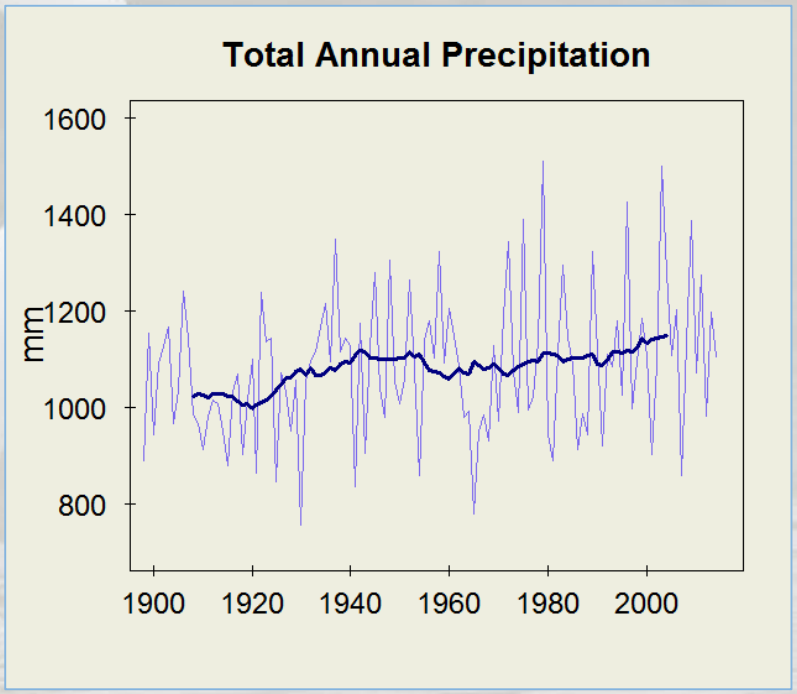
Total Annual Precipitation

The total amount of annual precipitation (as a liquid).

CBNERR-MD: +16.8 mm/decade (strong confidence)

CBNERR-VA: +5.2 mm/decade (strong confidence)

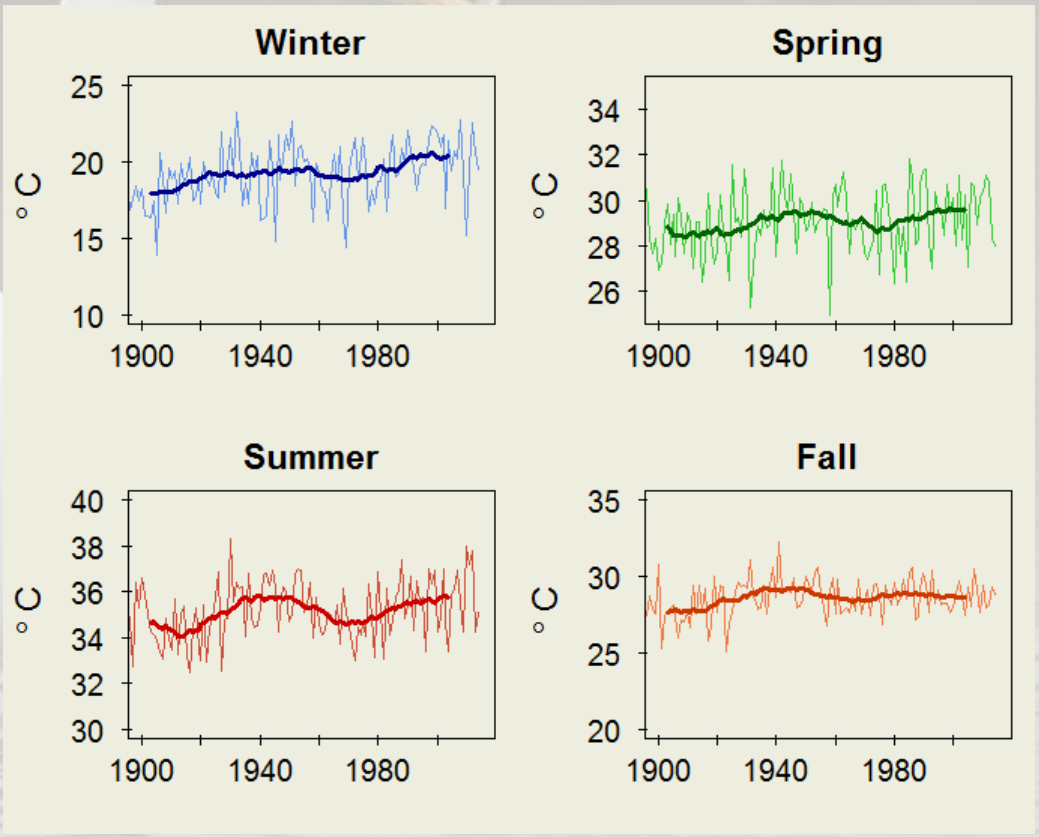
Future: +13.4 to +12.7 days/decade (strong confidence)



Tweetables: Historical annual precipitation has been increasing by 0.2 to 0.7 inches per decade.

TXx: The warmest Tmax reached each season.

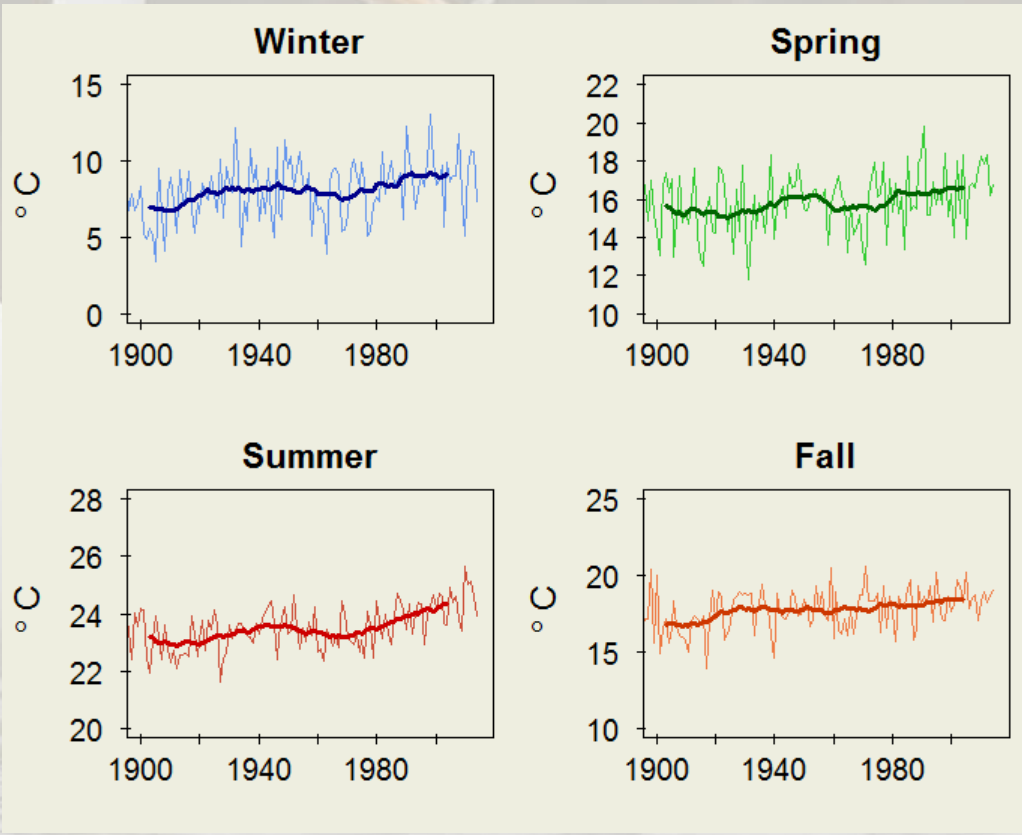
°C/decade	MD	VA	Future
Winter	0.5	0.3	+0.2 to +0.4
Spring	0.2	0.1▫	+0.3 to +0.6
Summer	0.2	0.1	+0.3 to +0.7
Fall	0.2	0.1▫	+0.3 to +0.8



Tweetables: The possibility of your ice cream melting faster due to summer heat is expected to increase.

TNx: The warmest Tmin reached each season.

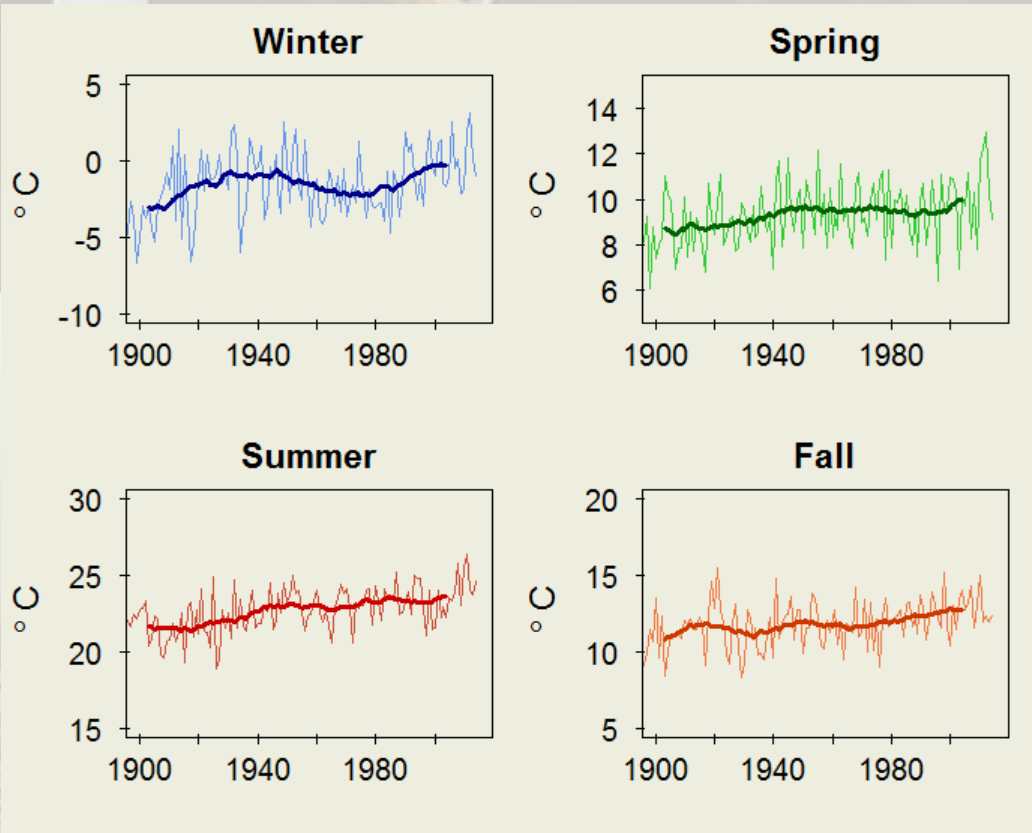
°C/decade	MD	VA	Future
Winter	+0.7	+0.3	+0.2 to +0.5
Spring	+0.6	+0.2	+0.6 to +0.2
Summer	+0.5	+0.1	+0.3 to +0.6
Fall	+0.4	+0.1	+0.3 to +0.6



Tweetables: The absolute warmest minimum temperature reached each season has increased. Prepare for warm nights!

TXn: The coolest Tmax reached each season.

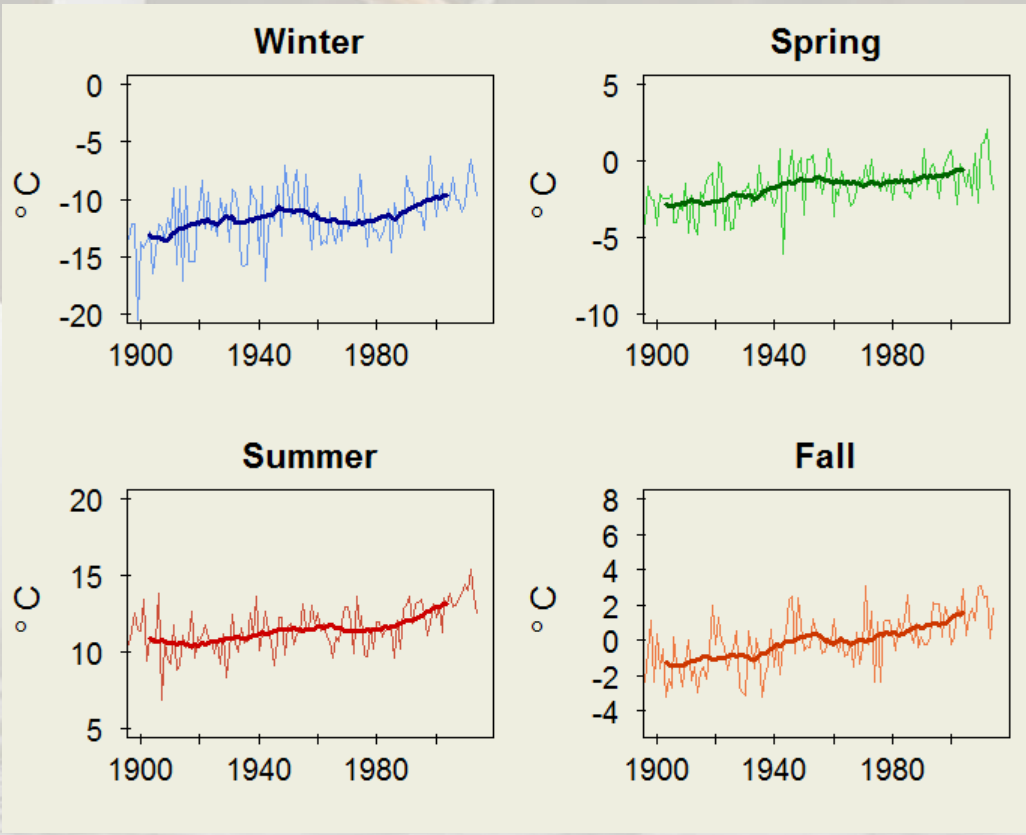
°C/decade	MD	VA	Future
Winter	+0.4	+0.2	+0.3 to +0.6
Spring	+0.3	+0.1	+0.3 to +0.6
Summer	+0.3	+0.3	+0.3 to +0.6
Fall	+0.5	+0.3	+0.3 to +0.6



Tweetables: Cold days are getting less cold. This could allow pests to survive longer.

TNn: The coolest Tmin reached each season.

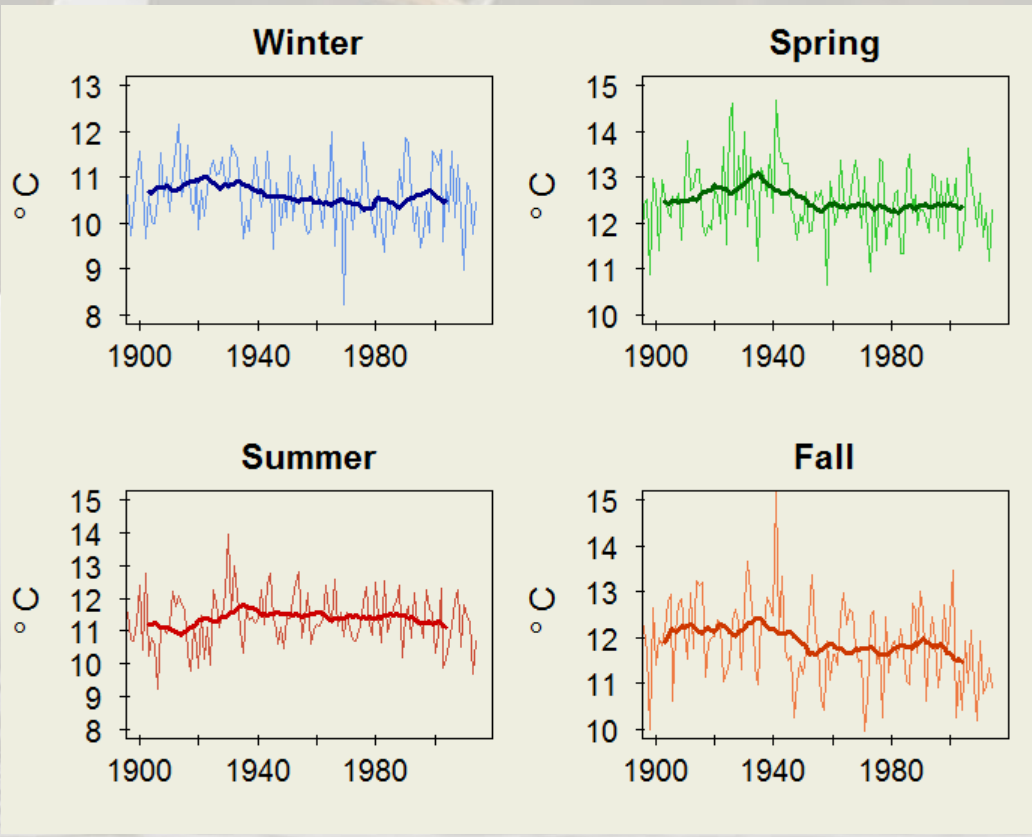
°C/decade	MD	VA	Future
Winter	+0.7	+0.5	+0.3 to +0.7
Spring	+0.8	+0.5	+0.3 to +0.5
Summer	+0.5	+0.4	+0.3 to +0.7
Fall	+0.8	+0.7	+0.3 to +0.7



Tweetables: The absolute coldest temperature reached each season has increased. Hope you like iced coffee!

DTR: Diurnal temperature range (Tmax-Tmin).

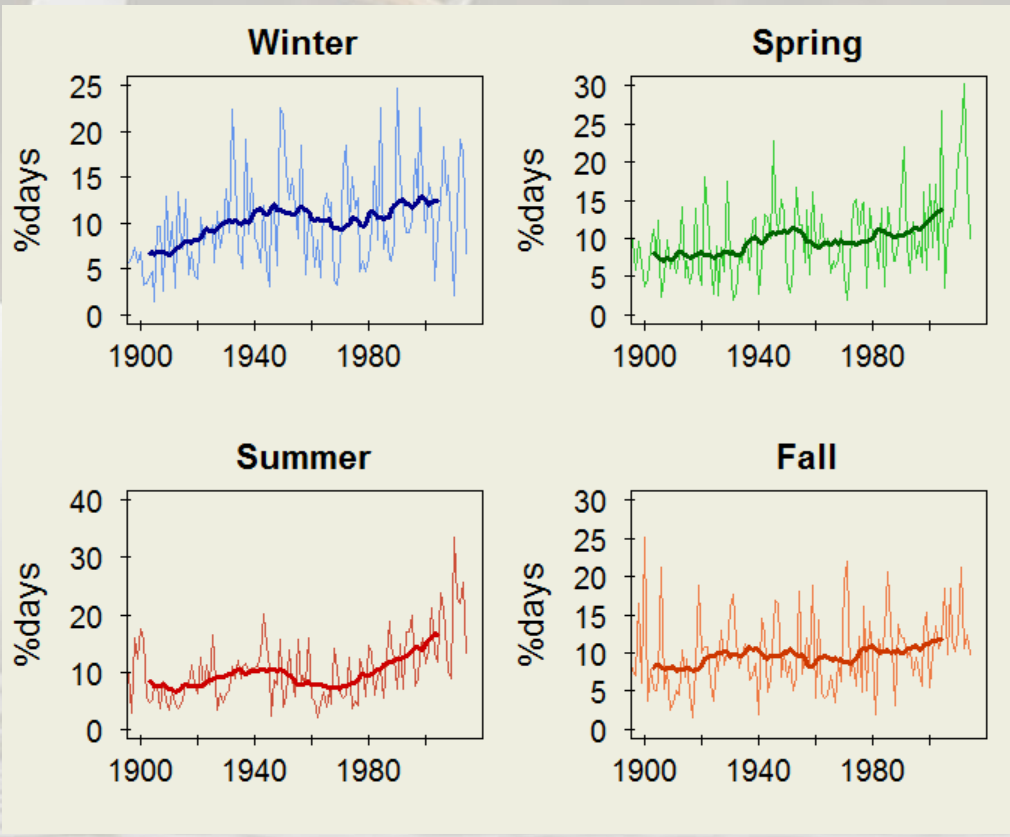
°C/decade	MD	VA	Future
Winter	-0.1	0▫	+0.01▪ to -0.02▫
Spring	-0.2	-0.1▫	+0.01▫ to +0.02▫
Summer	-0.1	-0.1▫	-0.01▫ to +0.03▫
Fall	-0.1	0	0▪ to -0.01▪



Tweetables: Not all extreme climate indices manifest in Chesapeake Bay. DTR varies by season and location!

TN90p: %days when Tmin > 90th percentile (Warm Nights).

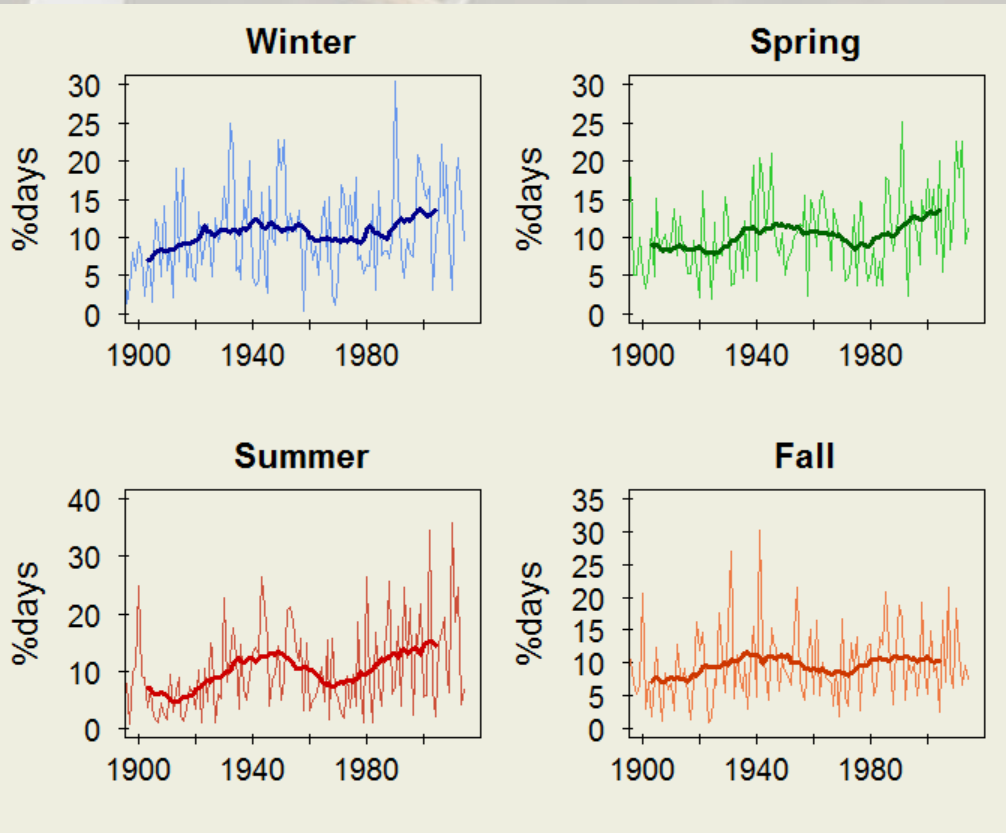
%days/decade	MD	VA	Future
Winter	+0.6	+0.4	+0.9 to +1.3
Spring	+0.8	+0.3	+2.0 to +5.0
Summer	+0.9	+0.4	+3.8 to +8.1
Fall	+0.3	+0.2▫	+0.9 to +2.8



Tweetables: Increases of warm summer nights is an indicator for organism heat stress, including humans!

TX90p: %days when Tmax > 90th percentile (Warm Days).

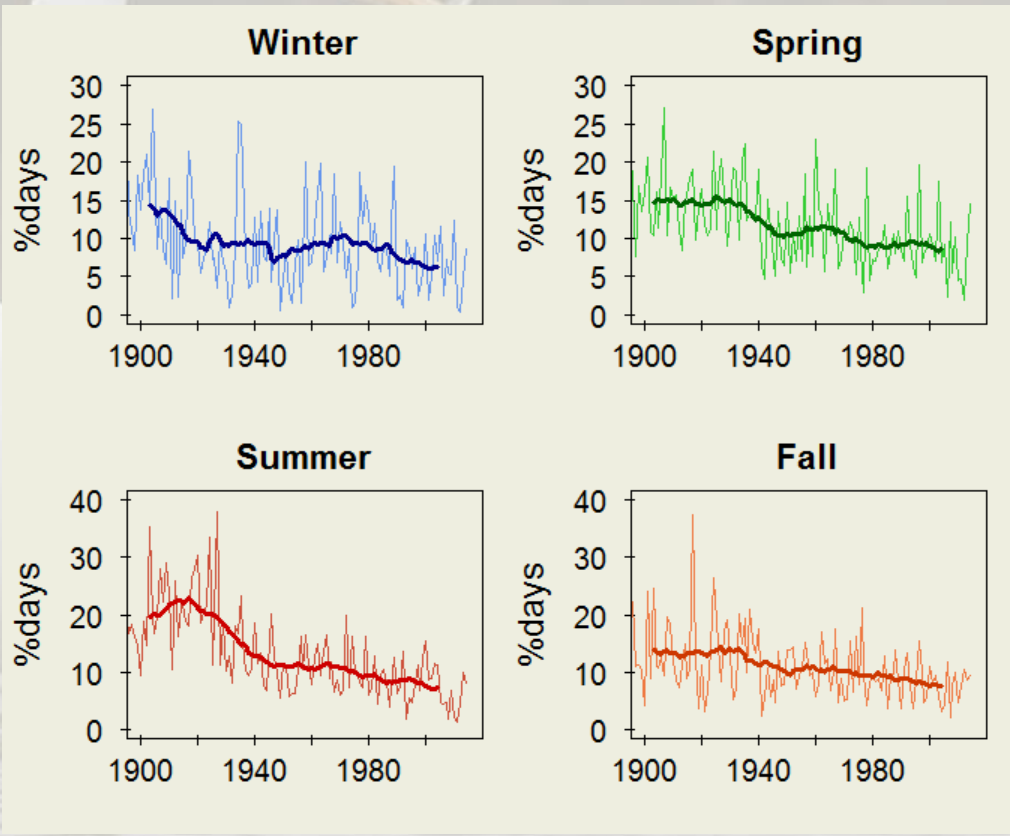
%days/decade	MD	VA	Future
Winter	+0.3	+0.3	+1.2 to +1.5
Spring	+0.3	+0.4	+2.3 to +5.5
Summer	+0.4	+0.7	+3.1 to +7.9
Fall	+0.1▫	+0.2	+1.5 to +3.9



Tweetables: Warm summer days are related to submerged aquatic vegetation dieback events.

TX10p: %days when Tmax < 10th percentile (Cool Days).

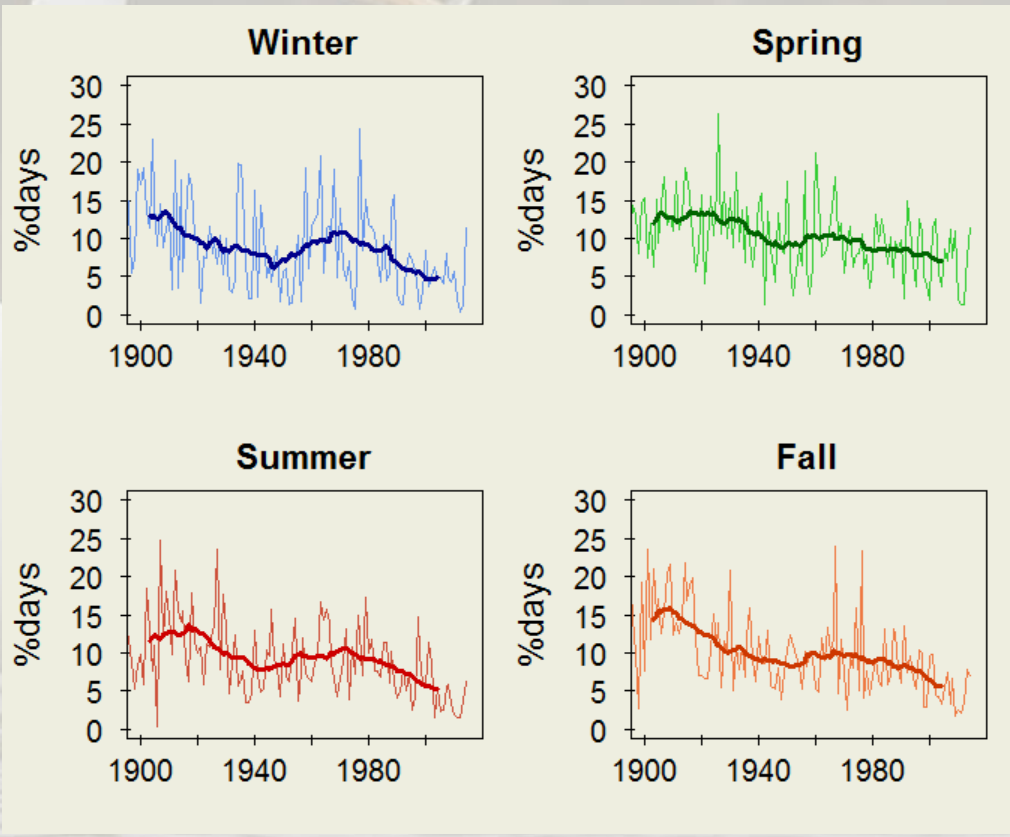
%days/decade	MD	VA	Future
Winter	-0.2▫	-0.6	-0.5 to -0.9
Spring	-0.4	-0.9▫	-0.5 to -0.8
Summer	-0.8	-1.9	-0.4 to -0.5
Fall	-0.4▫	-0.8	-0.5 to -0.7



Tweetables: Fewer cool days could allow non-indigenous species to move into the Chesapeake, like the Southern Flounder.

TN10p: %days when Tmin < 10th percentile (Cool Nights).

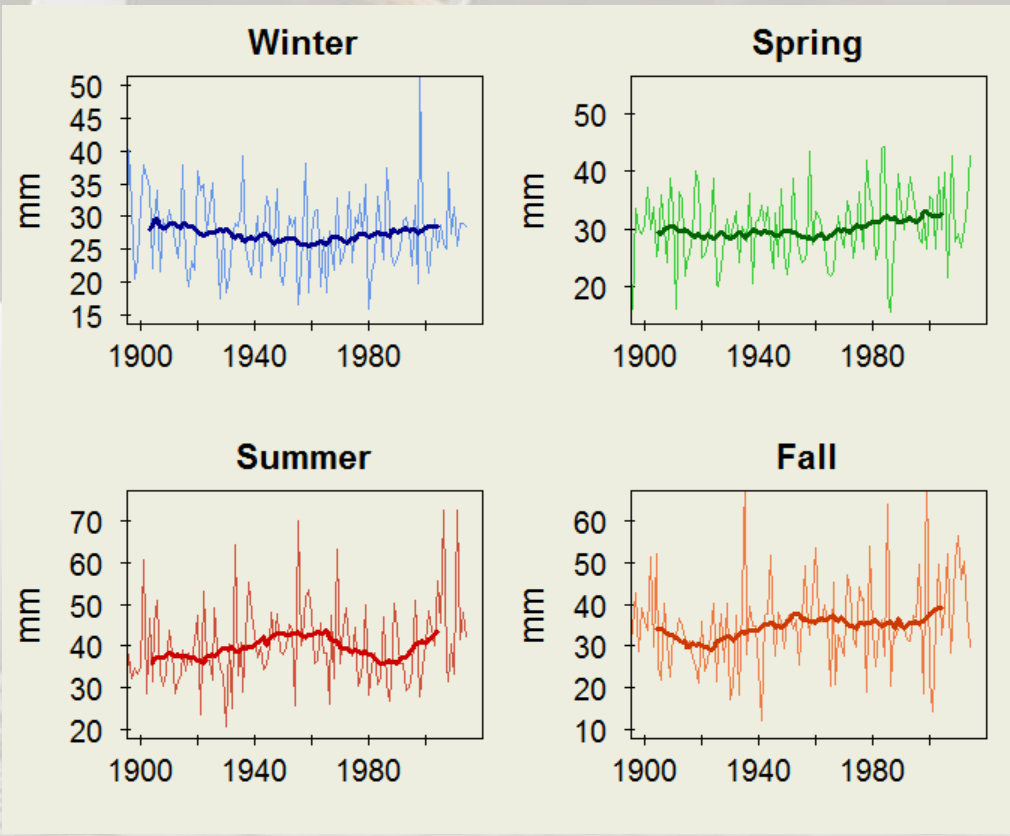
%days/decade	MD	VA	Future
Winter	-1.0	-0.3	-0.6 to -0.7
Spring	-1.9	-0.2▫	-0.5 to -0.6
Summer	-1.3	x	-0.5 to -0.5
Fall	-1.5	-0.1▫	-0.5 to -0.6



Tweetables: Changes in the amount of cool days could cause flowers to bloom early. Bad for migratory birds!

Rx1day: Greatest 1 day precipitation amount

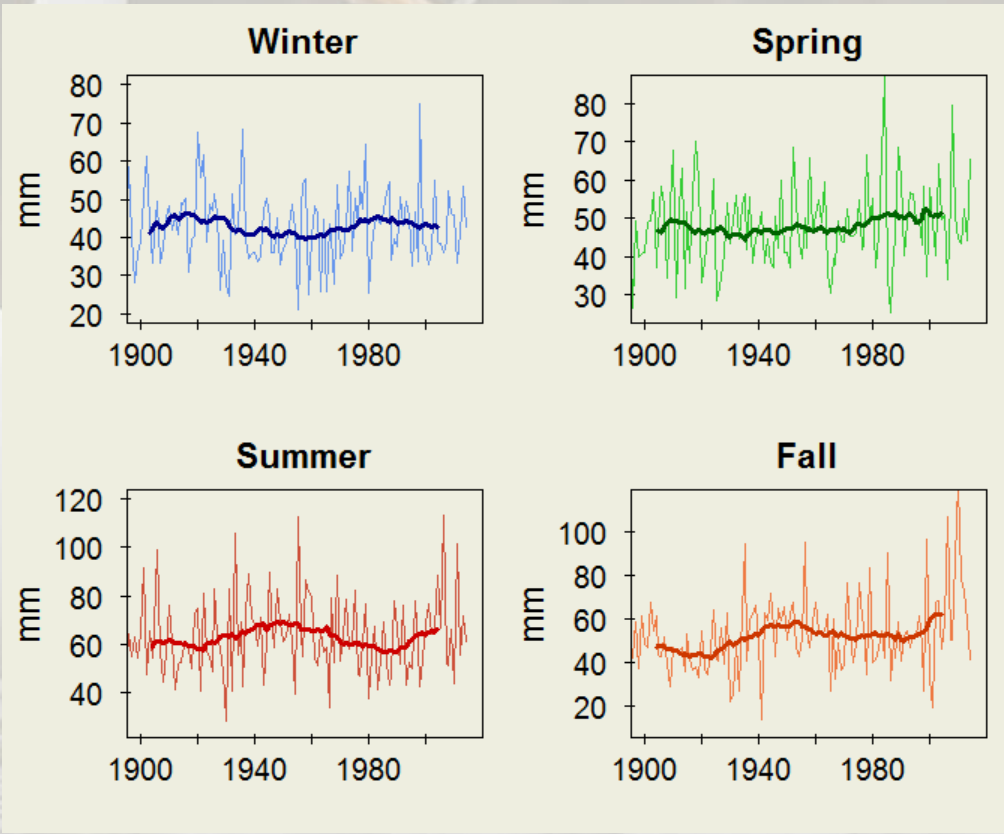
mm/decade	MD	VA	Future
Winter	+2.6	+1.3	+0.5 to +1.2
Spring	+4.1	+3.2	+0.2▫ to +1.0
Summer	+4.1	+5.0	+0.4▫ to +0.4▫
Fall	+4.5	+4.1	+0.1▫ to +0.6



Tweetables: Precipitation events are intensifying in Chesapeake Bay. Plant native gardens!

Rx5day: Greatest 5 day precipitation amount

mm/decade	MD	VA	Future
Winter	+4.2	+1.9	+0.8 to +1.4
Spring	+5.6	+3.0	+1.1 to +1.7
Summer	+2.8	+6.4	+0.9▫ to +1.1
Fall	+5.5	+6.3	+0.5 to +0.9



Tweetables: The greatest annual 5-day rain event is getting stronger. Road flooding could result due to increasing impervious surfaces.

Daily Percentile Values and Confidence

North (1961-1990)		10th	90th
Daily TMAX °C	winter	-0.6	15
	summer	25	33.3
	spring	8.9	27.2
	autumn	11.1	28.9
	annual	**4.4**	**31.1**
Daily TMIN °C	winter	-10	4.4
	summer	12.8	22.2
	spring	-1.7	15
	autumn	-0.6	18.3
	annual	**-4.4**	**20**

South (1961-1990)		10th	90th
Daily TMAX °C	winter	0.6	17.8
	summer	25.6	33.9
	spring	10	28.9
	autumn	12.2	29.4
	annual	**6.1**	**31.7**
Daily TMIN °C	winter	-9.4	5.6
	summer	13.3	22.8
	spring	-1.1	15.6
	autumn	0	18.9
	annual	**-3.9**	**20.6**

Daily PRCP (mm)	95th	99th
North	19.1	41.4
South	18.5	40.6

Key	Definition	Confidence
Level 4	3/3 significant, same direction	Strongly Confident
Level 3	2/3 significant, same direction	Very Confident
Level 2	3/3 significant, different directions	Somewhat Confident
Level 1	1/3 significant	Weakly Confident
Level 0	0/3 significant	Confident in No Trend